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# MARKING GUIDES FOR OAKS AND YELLOW-POPLAR IN THE SOUTHERN UPLANDS

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# MARKING GUIDES FOR OAKS AND YELLOW-POPLAR IN THE SOUTHERN UPLANDS

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This paper offers guides that the forest manager in the southern uplands can use to judge when his trees should be cut--that is, when they are financially mature. The paper was written with special reference to the territory about Birmingham, Alabama (figure 1), but the portions that deal with lumber logs and cross ties should be widely applicable in other upland hardwood forests in the South. The discussion is restricted to red oaks, white oaks, and yellow-poplar, and to the chief products into which these trees are cut: standard factory lumber, cross ties, and--in the Birmingham territory--mine props. Face veneer logs and tight cooperage bolts are not considered; forest managers who expect to grow large quantities of these products will need to make special studies following the principles outlined here.

The guides are not particularly complex in principle, but the alternatives to which they must be applied are numerous. Their use is facilitated by an understanding of the way in which they were constructed. Accordingly, this paper first describes how the guides were determined and how they apply to the various alternatives encountered in actual management. The last part (pp.26-27) condenses the guides into a simple set of marking rules for use in the woods.

The data on which the guides are based are the best available at present. Ideally, each forest manager would accumulate his own figures and work out his own guides following the principles described in this publication. This would, however, require data not always readily available; an alternative course is to adapt the guides offered here.

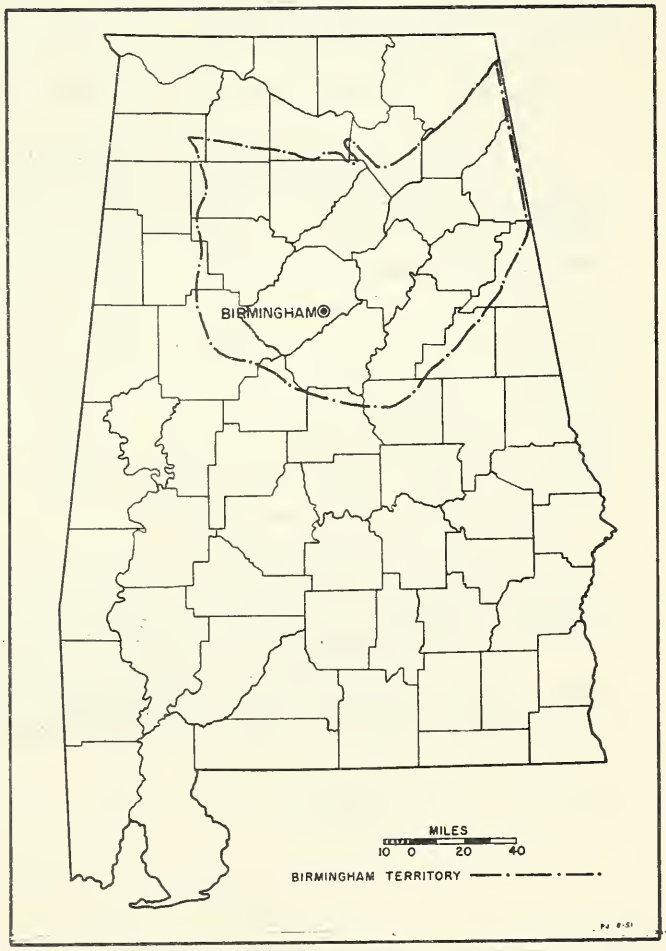


Figure 1.--Birmingham territory.

## How the Guides Were Determined

The guides are based on the cutting of financially mature timber. The idea of financial maturity is this:

From time to time the forest manager visits each acre of his holdings and marks for cutting those trees whose quality or growth rate is below par. Bearing in mind how the typical tree develops--low value at first, but rapid increase in value; then a gradual slackening in the rate of increase until the stage is finally reached where the tree ceases to pay its way--the manager appraises his trees with the object of putting the ax to those that are reaching this crucial point. This is the point of financial maturity. Just where it falls is determined by the rate at which the forest owner expects his trees to earn money, the so-called alternative rate of return.1/ If he expects a return of 4 percent, he will cut any tree that cannot produce at this rate.

The chief problem with which this paper is concerned, therefore, is to determine the rate of value increase that can be expected from a given tree over a given period of time. This rate will be estimated in the following steps:

1. Calculate the value of trees according to their volume, grade, and diameter.

2. Formulate reliable rules for judging the vigor of trees, as an index of their prospective diameter-growth rate.

3. Determine the prospective rate of increase in tree value.2/

Standard factory lumber makes up about 70 percent of total hardwood consumption and represents the highest general use of hardwood timber. In any operation aimed at growing lumber logs, however, cross ties and mine props will be harvested as a by-product from trees or portions of trees that for one reason or another are best not utilized as lumber logs. Too, at time of harvest those portions of lumber-log trees that can be more profitably utilized as face veneer or tight cooperage may be put to such use. In this paper, therefore, and following the steps listed above, trees will be appraised first for lumber logs, then for cross ties, and finally for mine props.

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1/. The choice of an alternative rate is conditioned by risk, taxes, business debts, and the like. See Duerr, Wm. A., and Bond, W. E. Optimum stocking of a selection forest. Jour. Forestry 50: 12-16. 1952.

2/. For more complete treatment of the method, see Guttenberg, Sam, and Putnam, J. A. Financial maturity of bottomland red oaks and sweetgum. South. Forest Expt. Sta., Occas. Paper 117, 24 pp. 1951.

## Lumber Logs

### Step one--tree volume, quality, and value

With standard factory lumber in view, tree volume is here expressed in board feet by the International ¼-inch kerf rule, using standard volume tables as the guide.[3] Tree quality is developed in terms of the log grades formulated by the U. S. Forest Products Laboratory[4]--for example, a two-log tree with a grade 1 butt and a grade 3 second log will be classed as grade 1-3. Since a description of these grades is readily available, they will not be discussed here. It must be recognized, however, that facility in the use of the grades is absolutely essential in making financial maturity decisions. Special training (which can be self-training) and experience in the field are required. Familiarity with the log defects upon which the grades are based is especially important.[5]

Tree value will be expressed in terms of conversion surplus.[6] Conversion surplus is the difference between the sales value of the end product (in this case, standard factory lumber) and all the direct (variable) costs of producing this lumber--mainly labor and materials used in felling the tree and in making, transporting, and sawing the logs. Conversion surplus thus represents that part of a tree's gross product value which can be made available to increase the profit or reduce the loss of the business.

Since conversion surplus will here be based upon lumber value--not log value or stumpage value--the examples to be developed will apply primarily to the timber owner who operates a sawmill and sells his product in the form of lumber. However, they will also apply to the log or stumpage seller who can count on receiving for each log or tree a price in line with the value of lumber it will yield. Indeed, prices would be in line on a freely competitive market if lumber producers and timber growers used such an analysis as a guide.

Lumber sales value.--The first ingredient of conversion surplus, lumber sales value, may be estimated for any tree. Knowing the grade and volume of each log in the tree and the lumber grade yield[7] of each grade of log, one may determine the amount of lumber, by grades, that

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3/. Mesavage, C., and Girard, J. W. Tables for estimating board-foot volume of timber. 94 pp. 1946. Govt. Printing Office.

4/. Hardwood log grades for standard lumber: proposals and results. U. S. Forest Products Laboratory D 1737. 1949.

5/. Lockard, C. R., Putnam, J. A., and Carpenter, R. D. Log defects in southern hardwoods. U. S. Dept. Agr., Agr. Handbook 4, 37 pp. 1950.

6/. Guttenberg, Sam, and Duerr, Wm. A. A guide to profitable tree utilization. South. Forest Expt. Sta., Occas. Paper 114, 18 pp. 1949.

7/. As given in reference cited in footnote 4.

the tree will yield. With current sales prices for lumber, he may then calculate the weighted average price per M of lumber represented in the tree, and from this the total lumber value in the tree.

The problem is how to allow for changes in the lumber market. An estimate of financial maturity involves looking ahead at least one cutting cycle--perhaps 5 years or more--and the lumber price level probably will not be the same then as now. To help solve this problem, advantage may be taken of the fact that with all the ups and downs of the lumber market, the price of each grade tends to maintain a fairly stable relationship to that of other grades.8/ Grade prices may then be expressed as percentages (index numbers) that will have substantial validity over the years, and the value of lumber in a tree may be calculated in index terms instead of dollars, following the same procedure as would be used with dollars.

In figure 2, value index numbers are plotted for each grade of red oak, white oak, and yellow-poplar lumber. These index numbers were derived from annual average lumber grade prices, expressed as relatives in percent of the price of No. 1 Common and Selects for the oaks and No. 1 Common for yellow-poplar. The chart covers the period 1925-1950, omitting the abnormal war years 1942 through 1945. These are representative price data, f.o.b. mills in the Birmingham territory, for air-dried stock 4/4-inch and thicker. The lower grades of lumber have commanded relatively high prices in recent years as these grades have come into wider demand. Since this condition appears likely to

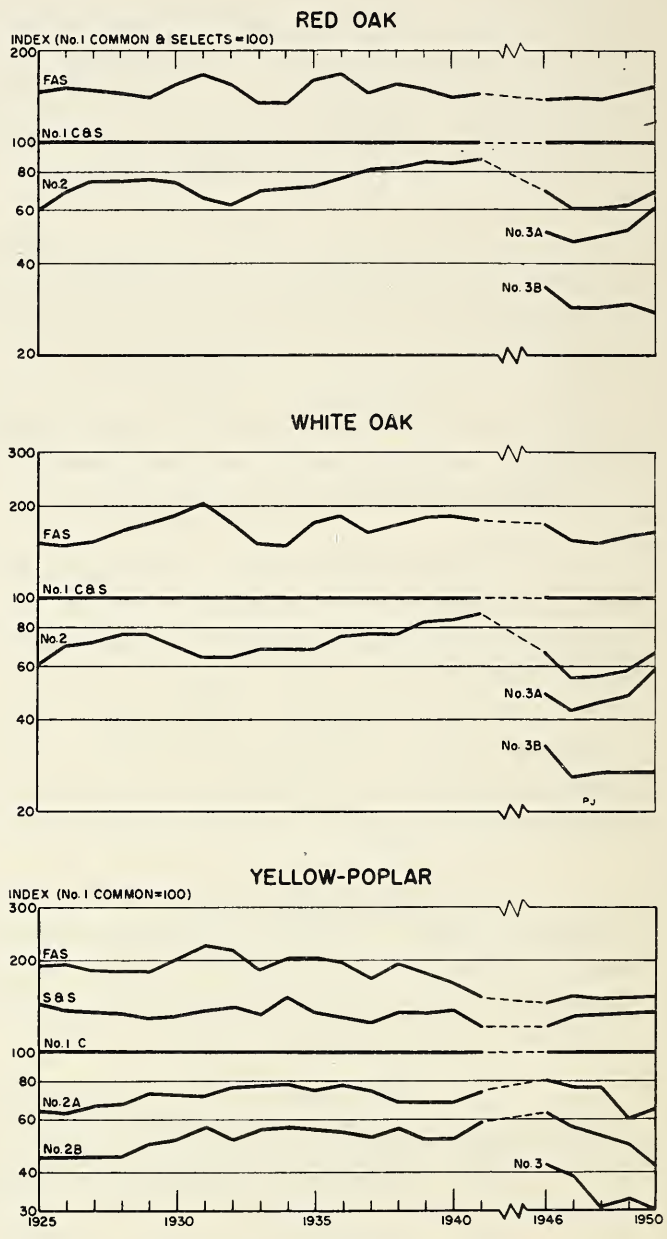


Figure 2.--Lumber grade index values per M board feet.

8/. Herrick, A. M. Grade yields and overrun from Indiana hardwood sawlogs. Purdue University Bul. 516, 59 pp. 1946.

continue, the index numbers used here were determined by averaging the price relatives for the years 1940, 1941, and 1946 through 1950, allowing each year equal weight. The resulting indexes are as follows:

| Lumber grade | Red Oak | White Oak | Yellow-poplar |
|---|---|---|---|
| Firsts and Seconds | 144 | 168 | 154 |
| Saps and Selects | ... | ... | 132 |
| No. 1 Common and Selects | 100 | 100 | ... |
| No. 1 Common | ... | ... | 100 |
| No. 2 Common | 71 | 68 | ... |
| No. 2A Common | ... | ... | 71 |
| No. 2B Common | ... | ... | 54 |
| No. 3 Common | ... | ... | 35 |
| No. 3A Common | 52 | 49 | ... |
| No. 3B Common | 30 | 28 | ... |

What these numbers mean--using red oak as an example--is that in any marketing period, whatever price is being received for No. 1 Common and Selects, 144 percent of that price will probably prevail for Firsts and Seconds. Seventy-one percent will prevail for No. 2 Common, 52 percent for No. 3A Common, and 30 percent for No. 3B Common.

Direct costs.--The other ingredient of conversion surplus, direct costs of lumber production from stump through mill, is estimated from whatever representative cost records are available. Direct costs include only those additional outlays that arise because the tree in question is being made into lumber. They specifically exclude all fixed or overhead costs--all costs that are unaffected by whether the particular tree is logged and milled.

For Birmingham territory hardwoods, available logging and milling study experience[9/] was used to estimate direct costs on a typical operation. Costs were estimated in dollars per M board feet for trees of each species group, diameter class, and log height. Dollars were then converted to relatives in percent of the price of No. 1 Common and Selects for oaks and No. 1 Common for yellow-poplar, just as was done for lumber value. This procedure is defensible on the ground that prices and direct costs (primarily wages) tend to fluctuate together. It permits deriving conversion surplus as an index

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9/. See publications cited on page 18 of the reference given in footnote 6, and James, L. M. Logging and milling studies in the southern Appalachian region. Southeastern Forest Expt. Sta. Tech. Notes 62 and 63. 1946.

number, and thus avoiding the problem of fluctuating costs and market prices. The result of these calculations is given below under step three.

Step two--vigor

Any woodsman can readily point out differences in tree vigor. Furthermore, there is no trick to spotting trees of very poor vigor, nor is there much question about cutting such trees for whatever value they may contain. Here we are concerned with enhancing a skill already possessed by woodsmen, so that tree vigor may be classified and used as an index of prospective growth. Three classes--high, medium, and low (excluding decadent trees)--suffice for all practical purposes and are clearly enough distinguished so that one can learn to identify them with minimum use of an increment borer.

Tree vigor can be judged from external indicators. The single most reliable indicator is the bark. Bark features stand out so strongly and are apparently so reliable that some others--site, age, root system--can largely be ignored. The crown, however, furnishes additional evidence and should be considered.

Bark features for the various vigor classes are illustrated in figures 3 through 5 (pages 9 - 11). The illustrations and the specific bark features described below apply mainly to trees 12 inches d.b.h. and over. The general indications of vigor furnished by the bark and crown, however, apply to trees of all sizes.

Red oaks (fig. 3) of high vigor generally have smooth, thin bark with wide, open fissures vividly colored at the bottom. As vigor declines, the bark thickens and roughens, and the fissures narrow, becoming discontinuous and obscure in low-vigor trees. Decadent red oaks, those below the class of low vigor, are usually degenerate or dying. The bark is thick, dark, and very rough (fig. 3D) or else dull, bleached, and sickly. Excessive die-back of twigs often makes the tree stagheaded.

White oaks (fig. 4) of high vigor generally have thick, dark-gray bark with distinct, long fissures; ridges are flat with few cross breaks. As vigor declines, the bark thins and turns ash-gray, while fissures become obscure, ridges scaly, and cross breaks more numerous. In white oaks the most conclusive indicator of decadence occurs when one or more faces have very thin bark.

Yellow-poplars (fig. 5) of high vigor generally have bark that is shallowly ridged, somewhat corky, and light ash-grey. The fissures display light-colored inner bark at the bottom. As vigor falls off, the ridges become more distinct and closer together, and the color

darkens. The inner bark tissue disappears as low vigor is reached. Decadent yellow-poplars have very pronounced fissures, and the bark, by contrast with healthy trees, is bleached and sickly.

Table 1 summarizes the features of the three vigor classes for yellow-poplar (Liriodendron tulipifera) and for the better oak alternatives of the Birmingham territory--northern red oak (Quercus borealis), southern red oak (Q. falcata), and white oak (Q. alba). Vigor classes for scarlet oak (Q. coccinea) and black oak (Q. velutina) follow closely those for northern and southern red oak. Chestnut oak (Q. montana) and post oak (Q. stellata), however, differ markedly from white oak in the vigor indications furnished by the bark, though not in those displayed by the crowns.

The growth rates to be expected from trees (including all oaks mentioned above) in the three vigor classes are as follows:

Five-year average diameter growth (inches)

| Vigor | Red oaks | White oaks | Yellow-poplar |
|---|---|---|---|
| High | 1.50-2.00 | 1.00-1.50 | 1.75-2.25 |
| Medium | 1.00-1.50 | .75-1.00 | 1.25-1.75 |
| Low | .50-1.00 | .50- .75 | .75-1.25 |

Step three--value increase

With vigor classes defined, and with a method determined for expressing tree value according to tree size and quality, we are ready for the problem of growth in value--i.e., rate of increase in tree value, the rate that is to be compared with the desired rate of return to determine if a tree is financially mature. The problem will be considered in two stages: first, rate of value increase when a tree changes diameter but not log height or grade; second, rate of increase when height or grade, as well as diameter, changes.

A 5-year cutting cycle will be assumed. That is, it will be supposed--and this is realistic for the region--that the manager has the choice of cutting a tree now or waiting at least 5 years. Consequently our interest centers on the rate of tree-value increase in 5 years.

No change in log height or grade.--Rates of value increase for red oaks, white oaks, and yellow-poplar of each vigor class are worked out in tables 2, 3, and 4. In each table, columns 2, 3, and 4 show, in terms of index numbers as explained earlier, the lumber value, the direct costs, and the difference between these two--the conversion surplus--per M board feet as a weighted average for the tree. From the number of board feet per tree (column 5), conversion surplus per

(Text continued on p. 18.)

Table 1.--Crown and bark characteristics of red oaks, white oaks, and yellow-poplar, by vigor class

| High vigor | Medium vigor | Low vigor |
|---|---|---|
| **RED OAKS** | | |
| Bark: Bark thickness, and color of the inner and outer bark, varies with the species. In general, the bark is healthy, fully normal in color, relatively thin and smooth, but with shallow fissures exposing fleshy, lighter-colored inner bark that contrasts markedly with dark outer bark. The bark is the most conclusive indicator. | Bark: Compared with high vigor, fissures less wide, inner bark duller and generally less conspicuous. Overall, bark is somewhat rougher and darker. | Bark: Dark, thick, narrowly fissured. Little or no live tissue exposed in fissures. |
| Crown: 3/4 or more fully formed and without close competition. Full and thrifty. Profuse long, upward-reaching young branches and twigs, light-colored and lustrous. No dying leaders or dead stubs in upper crown. Foliage abundant and lustrous. | Crown: 1/2 or more well-formed, with abundant foliage, and without close competition. Some crowns may be entirely free of competition, but twigs will be thicker and fewer, and foliage scantier, than in high-vigor crowns. | Crown: Small and poorly formed, or open. Thinly foliated. |
| Crown quality and vigor more important than length or volume, except that a high ratio of crown length to stem length is significant indicator. | | |
| **WHITE OAKS** | | |
| Bark: Thick, dark-gray with distinct, long fissures. Ridges flat with few cross breaks running from fissure to fissure. | Bark: Thinner. Gray. Fissures shorter and less distinct, ridges somewhat scaly, cross breaks more common. | Bark: Thin. Ash-gray. Fissures short and obscure, ridges scaly, and cross breaks abundant. |
| Crown: 3/4 or more fully formed and without close competition. Full and thrifty, branches small, silvery, and ascending. No dying leaders or dead stubs in upper crown. | Crown: 1/2 or more fully formed and without close competition. Notably less full than those of high vigor trees. Branches darker, less ascending in aspect. | Crown: Small and poorly formed, or open. Thinly foliated. |
| **YELLOW-POPLAR** | | |
| Bark: Corky but shallowly ridged, light ash-grey. Diamond-shaped fissures display light-colored inner bark. | Bark: Thicker. Ash-grey. Ridges more pronounced. Some inner bark visible in fissures. | Bark: Thick. Dark grey. Fissures deep and very pronounced. No inner bark visible. |
| Crown: 2/3 or more fully formed and without close competition. Full and healthy, composed preponderantly of small ascending leaders and twigs. Foliage abundant and lustrous. Sharp pointed crown an important indicator. | Crown: 1/2 or more fully formed and without close competition. Crowns notably less full and less pointed than those of high vigor trees. Crown limbs are larger and do not ascend as steeply as in high-vigor crowns. | Crown: Small and poorly formed. Thinly foliated. Branches relatively dark in color and spreading rather than reaching in aspect. |

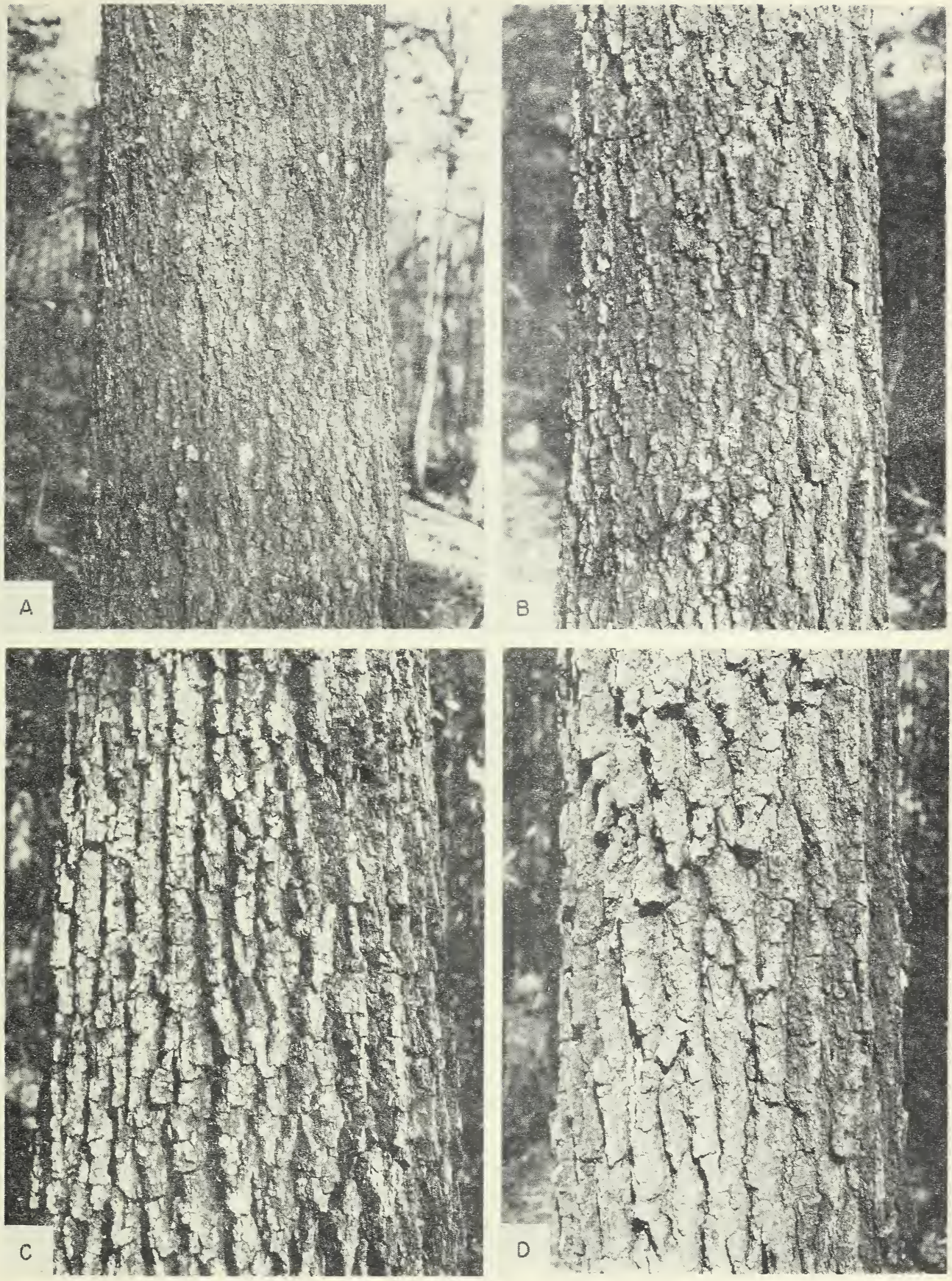


Figure 3.--Southern red oak. A, High vigor. B, Medium vigor. C, Low vigor. D, Decadent.

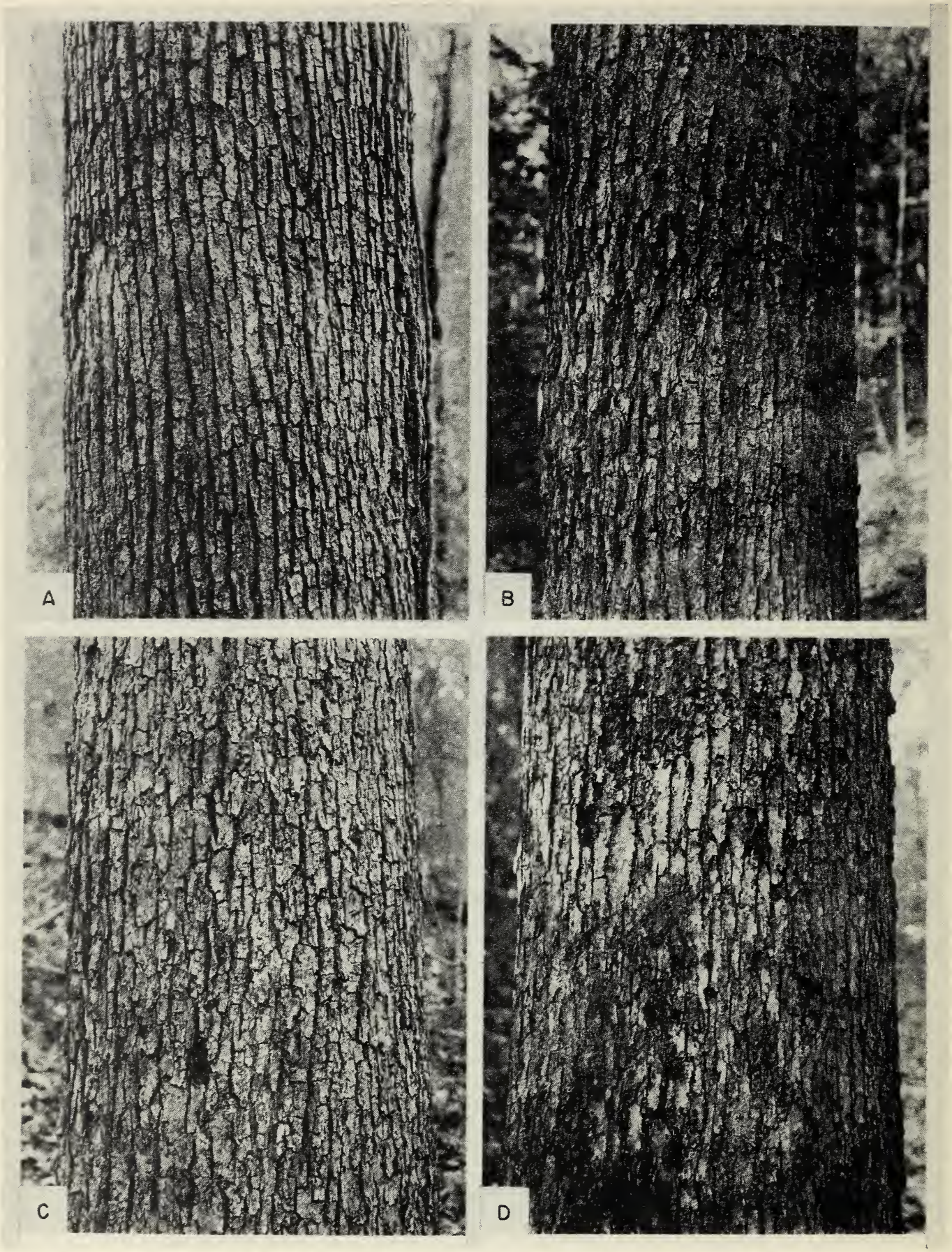


Figure 4.--White oak. A, High vigor. B, Medium vigor. C, Low vigor. D, Decadent.

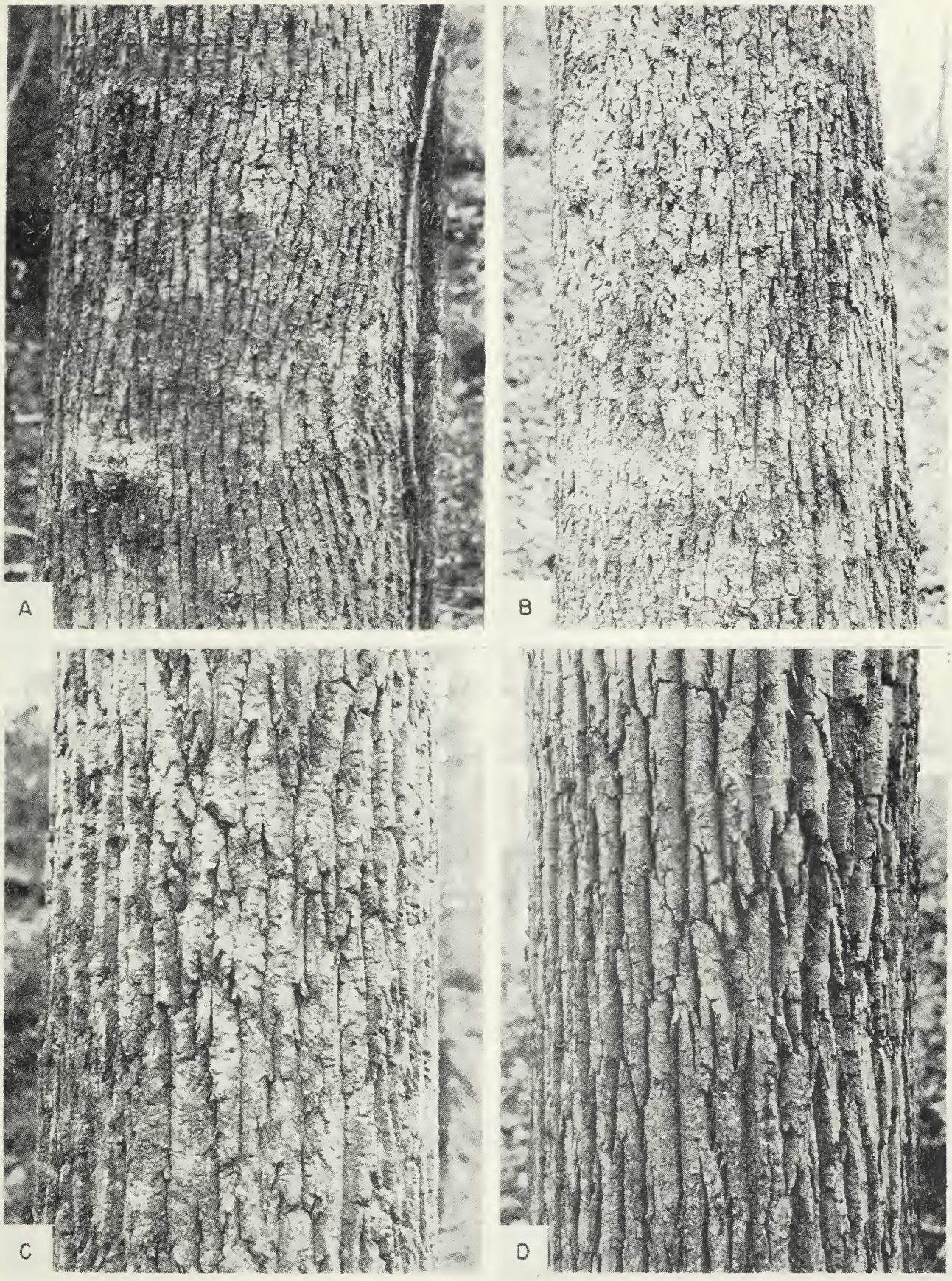


Figure 5.--Yellow-poplar. A, High vigor. B, Medium vigor. C, Low vigor. D, Decadent.

Table 2.--Rate of value increase of red oaks, by log height, grade, diameter, and vigor class

| Diam. breast high (inches) (1) | Per M board feet: Gross lumber value (2) | Direct costs (3) | Conversion surplus (4) | Lumber per tree (5) | Conversion surplus per tree by vigor class: Now (6) | High vigor: After 5 yrs. (7) | High vigor: Annual increase (8) | Medium vigor: After 5 yrs. (9) | Medium vigor: Annual increase (10) | Low vigor: After 5 yrs. (11) | Low vigor: Annual increase (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | | | Bd.ft. | Index | | Percent | Index | Percent | Index | Percent |
| | | | | | 1-LOG-TREES, GRADE 1 | | | | | | |
| 18 | 92.2 | 61.4 | 30.8 | 112 | 3.45 | 5.40 | 9.4 | 4.85 | 7.0 | 4.30 | 4.5 |
| 20 | 95.9 | 55.6 | 40.3 | 141 | 5.68 | 7.80 | 6.5 | 7.20 | 4.9 | 6.60 | 3.0 |
| 22 | 97.6 | 51.0 | 46.6 | 174 | 8.11 | 10.55 | 5.4 | 9.85 | 4.0 | 9.15 | 2.4 |
| 24 | 99.4 | 47.5 | 51.9 | 209 | 10.85 | 13.60 | 4.6 | 12.85 | 3.4 | 12.05 | 2.1 |
| 26 | 101.3 | 44.7 | 56.6 | 248 | 14.04 | 17.05 | 4.0 | 16.20 | 2.9 | 15.35 | 1.8 |
| 28 | 103.4 | 42.6 | 60.8 | 289 | 17.57 | 21.00 | 3.6 | 20.00 | 2.6 | 19.00 | 1.6 |
| 30 | 105.6 | 41.2 | 64.4 | 334 | 21.51 | 25.28 | 3.3 | 24.20 | 2.4 | 23.13 | 1.5 |
| 32 | 108.0 | 40.4 | 67.6 | 382 | 25.82 | 29.80 | 2.9 | 28.66 | 2.1 | 27.53 | 1.3 |
| | | | | | GRADE 2 | | | | | | |
| 18 | 70.0 | 61.4 | 8.6 | 112 | .96 | 2.15 | 17.5 | 1.80 | 13.3 | 1.45 | 8.6 |
| 20 | 71.9 | 55.6 | 16.3 | 141 | 2.30 | 3.70 | 10.0 | 3.30 | 7.5 | 2.90 | 4.7 |
| 22 | 73.8 | 51.0 | 22.8 | 174 | 3.97 | 5.60 | 7.1 | 5.10 | 5.1 | 4.60 | 3.0 |
| 24 | 75.8 | 47.5 | 28.3 | 209 | 5.91 | 7.95 | 6.1 | 7.35 | 4.5 | 6.80 | 2.8 |
| 26 | 78.0 | 44.7 | 33.3 | 248 | 8.26 | 10.55 | 5.0 | 9.90 | 3.7 | 9.25 | 2.3 |
| 28 | 80.2 | 42.6 | 37.6 | 289 | 10.87 | 13.45 | 4.4 | 12.75 | 3.2 | 12.00 | 2.0 |
| 30 | 82.6 | 41.2 | 41.4 | 334 | 13.83 | 16.80 | 4.0 | 15.95 | 2.9 | 15.05 | 1.7 |
| 32 | 85.5 | 40.4 | 45.1 | 382 | 17.23 | 20.05 | 3.0 | 19.30 | 2.3 | 18.50 | 1.4 |
| | | | | | GRADE 3 | | | | | | |
| 20 | 56.8 | 55.6 | 1.2 | 141 | .17 | 1.00 | 55.1 | .75 | 34.5 | .50 | 24.0 |
| 22 | 57.5 | 51.0 | 6.5 | 174 | 1.13 | 2.10 | 13.2 | 1.85 | 10.4 | 1.60 | 7.2 |
| 24 | 58.2 | 47.5 | 10.7 | 209 | 2.24 | 3.35 | 8.4 | 3.05 | 6.4 | 2.75 | 4.2 |
| 26 | 59.1 | 44.7 | 14.4 | 248 | 3.57 | 4.80 | 6.1 | 4.40 | 4.3 | 4.05 | 2.6 |
| 28 | 60.0 | 42.6 | 17.4 | 289 | 5.03 | 6.40 | 4.9 | 6.00 | 3.6 | 5.65 | 2.4 |
| 30 | 61.2 | 41.2 | 20.0 | 334 | 6.68 | 8.20 | 4.2 | 7.80 | 3.1 | 7.30 | 1.8 |
| 32 | 62.7 | 40.4 | 22.3 | 382 | 8.52 | 9.90 | 3.0 | 9.50 | 2.2 | 9.10 | 1.3 |
| | | | | | 2-LOG-TREES, GRADE 1-2 | | | | | | |
| 18 | 87.0 | 60.2 | 26.8 | 210 | 5.63 | 8.55 | 8.7 | 7.75 | 6.6 | 6.90 | 4.1 |
| 20 | 88.3 | 54.5 | 33.8 | 266 | 8.99 | 12.60 | 7.0 | 11.55 | 5.1 | 10.50 | 3.1 |
| 22 | 89.6 | 49.8 | 39.8 | 331 | 13.17 | 17.15 | 5.4 | 16.00 | 4.0 | 14.85 | 2.4 |
| 24 | 91.0 | 46.2 | 44.8 | 397 | 17.79 | 22.40 | 4.7 | 21.05 | 3.4 | 19.80 | 2.2 |
| 26 | 92.5 | 43.8 | 48.7 | 475 | 23.13 | 28.20 | 4.0 | 26.70 | 2.9 | 25.25 | 1.8 |
| 28 | 94.1 | 41.9 | 52.2 | 554 | 28.92 | 34.80 | 3.8 | 33.05 | 2.7 | 31.40 | 1.6 |
| 30 | 95.9 | 40.6 | 55.3 | 646 | 35.72 | 42.05 | 3.3 | 40.20 | 2.4 | 38.40 | 1.5 |
| 32 | 97.9 | 40.0 | 57.9 | 743 | 43.02 | 49.50 | 2.8 | 47.65 | 2.1 | 45.80 | 1.3 |
| | | | | | GRADE 1-3 | | | | | | |
| 18 | 74.0 | 60.2 | 13.8 | 210 | 2.90 | 5.35 | 13.0 | 4.60 | 9.7 | 3.95 | 6.4 |
| 20 | 76.1 | 54.5 | 21.6 | 266 | 5.75 | 8.95 | 9.3 | 8.00 | 6.8 | 7.05 | 4.2 |
| 22 | 78.2 | 49.8 | 28.4 | 331 | 9.40 | 13.00 | 6.7 | 12.00 | 5.0 | 10.95 | 3.1 |
| 24 | 80.4 | 46.2 | 34.2 | 397 | 13.58 | 17.80 | 5.6 | 16.60 | 4.1 | 15.35 | 2.5 |
| 26 | 82.7 | 43.8 | 38.9 | 475 | 18.48 | 23.20 | 4.6 | 21.90 | 3.5 | 20.50 | 2.1 |
| 28 | 85.2 | 41.9 | 43.3 | 554 | 23.99 | 29.55 | 4.3 | 27.95 | 3.1 | 26.35 | 1.9 |
| 30 | 87.7 | 40.6 | 47.1 | 646 | 30.43 | 36.50 | 3.7 | 34.75 | 2.7 | 32.95 | 1.6 |
| 32 | 90.4 | 40.0 | 50.4 | 743 | 37.45 | 43.35 | 3.0 | 41.70 | 2.2 | 40.00 | 1.3 |

Table 2 .--(Continued)

| Diam. breast high (inches) (1) | Per M board feet: Gross lumber value (2) | Direct costs (3) | Conversion surplus (4) | Lumber per tree (5) | Conversion surplus per tree by vigor class: Now (6) | High vigor: After 5 yrs. (7) | High vigor: Annual increase (8) | Medium vigor: After 5 yrs. (9) | Medium vigor: Annual increase (10) | Low vigor: After 5 yrs. (11) | Low vigor: Annual increase (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | | | Bd.ft. | Index | | Percent | Index | Percent | Index | Percent |
| | | | | | GRADE 2-3 | | | | | | |
| 18 | 62.6 | 60.2 | 2.4 | 210 | .50 | 2.25 | 33.6 | 1.80 | 29.2 | 1.25 | 16.5 |
| 20 | 63.9 | 54.5 | 9.4 | 266 | 2.50 | 4.80 | 13.9 | 4.15 | 10.6 | 3.50 | 6.9 |
| 22 | 65.4 | 49.8 | 15.6 | 331 | 5.16 | 7.75 | 8.5 | 7.00 | 6.3 | 6.20 | 3.7 |
| 24 | 66.8 | 46.2 | 20.6 | 397 | 8.18 | 11.20 | 6.5 | 10.35 | 4.8 | 9.50 | 3.0 |
| 26 | 68.5 | 43.8 | 24.7 | 475 | 11.73 | 15.15 | 5.2 | 14.20 | 3.9 | 13.20 | 2.4 |
| 28 | 70.3 | 41.9 | 28.4 | 554 | 15.73 | 20.00 | 4.9 | 18.80 | 3.6 | 17.55 | 2.2 |
| 30 | 72.5 | 40.6 | 31.9 | 646 | 20.61 | 25.55 | 4.4 | 24.10 | 3.2 | 22.75 | 2.0 |
| 32 | 75.4 | 40.0 | 35.4 | 743 | 26.30 | 30.60 | 3.1 | 29.40 | 2.2 | 28.20 | 1.4 |
| 34 | 77.2 | 40.1 | 37.1 | 841 | 31.20 | 34.80 | 2.2 | 33.85 | 1.6 | 32.80 | 1.0 |
| | | | | | GRADE 3-3 | | | | | | |
| 22 | 53.0 | 49.8 | 3.2 | 331 | 1.06 | 2.60 | 19.6 | 2.15 | 15.2 | 1.75 | 10.5 |
| 24 | 53.3 | 46.2 | 7.1 | 397 | 2.82 | 4.42 | 9.4 | 4.00 | 7.2 | 3.55 | 4.7 |
| 26 | 53.7 | 43.8 | 9.9 | 475 | 4.70 | 6.55 | 6.8 | 6.00 | 5.0 | 5.45 | 3.0 |
| 28 | 54.2 | 41.9 | 12.3 | 554 | 6.81 | 8.95 | 5.6 | 8.35 | 4.2 | 7.85 | 2.9 |
| 30 | 54.9 | 40.6 | 14.3 | 646 | 9.24 | 11.43 | 4.3 | 10.80 | 3.2 | 10.15 | 1.9 |
| 32 | 55.9 | 40.0 | 15.9 | 743 | 11.81 | 13.80 | 3.2 | 13.20 | 2.2 | 12.15 | 1.4 |
| 34 | 56.7 | 40.1 | 16.6 | 841 | 13.96 | 15.55 | 2.2 | 15.15 | 1.6 | 14.70 | 1.0 |
| | | | | | 3-LOG-TREES, GRADE 1-1-2 | | | | | | |
| 22 | 91.5 | 49.5 | 42.0 | 475 | 19.95 | 26.60 | 5.9 | 24.60 | 4.3 | 22.65 | 2.6 |
| 24 | 93.1 | 45.5 | 47.6 | 580 | 27.61 | 34.50 | 4.5 | 32.50 | 3.3 | 30.55 | 2.0 |
| 26 | 94.6 | 43.2 | 51.4 | 690 | 35.47 | 43.55 | 4.2 | 41.20 | 3.0 | 39.00 | 1.9 |
| 28 | 96.5 | 41.5 | 55.0 | 814 | 44.77 | 53.64 | 3.7 | 51.05 | 2.7 | 48.40 | 1.6 |
| 30 | 98.4 | 40.3 | 58.1 | 945 | 54.90 | 65.00 | 3.4 | 62.00 | 2.5 | 59.20 | 1.5 |
| 32 | 100.7 | 39.8 | 60.9 | 1,092 | 66.50 | 75.90 | 2.7 | 73.35 | 2.0 | 70.60 | 1.2 |
| | | | | | GRADE 1-1-3 | | | | | | |
| 22 | 88.0 | 49.5 | 38.5 | 475 | 18.29 | 24.45 | 6.0 | 22.65 | 4.4 | 20.85 | 2.7 |
| 24 | 89.2 | 45.5 | 43.7 | 580 | 25.35 | 31.80 | 4.6 | 29.95 | 3.4 | 28.07 | 2.1 |
| 26 | 90.6 | 43.2 | 47.4 | 690 | 32.71 | 40.05 | 4.1 | 38.00 | 3.0 | 35.85 | 1.8 |
| 28 | 92.0 | 41.5 | 50.5 | 814 | 41.11 | 49.20 | 3.7 | 46.80 | 2.6 | 44.55 | 1.6 |
| 30 | 93.6 | 40.3 | 53.3 | 945 | 50.37 | 59.45 | 3.4 | 56.80 | 2.4 | 54.15 | 1.5 |
| 32 | 95.5 | 39.8 | 55.7 | 1,092 | 60.82 | 69.60 | 2.8 | 67.15 | 2.0 | 64.60 | 1.2 |
| | | | | | GRADE 1-2-3 | | | | | | |
| 18 | 76.5 | 59.5 | 17.0 | 302 | 5.13 | 8.80 | 11.4 | 7.70 | 8.4 | 6.60 | 5.2 |
| 20 | 78.4 | 54.0 | 24.4 | 384 | 9.37 | 14.00 | 8.3 | 12.60 | 6.1 | 11.25 | 3.7 |
| 22 | 80.5 | 49.5 | 31.0 | 475 | 14.72 | 20.60 | 6.9 | 18.95 | 5.2 | 17.20 | 3.2 |
| 24 | 82.6 | 45.5 | 37.1 | 580 | 21.52 | 27.80 | 5.2 | 25.95 | 3.8 | 24.15 | 2.3 |
| 26 | 84.9 | 43.2 | 41.7 | 690 | 28.77 | 36.10 | 4.6 | 34.00 | 3.4 | 31.90 | 2.1 |
| 28 | 87.2 | 41.5 | 45.7 | 814 | 37.20 | 45.55 | 4.1 | 43.15 | 3.0 | 40.75 | 1.8 |
| 30 | 89.8 | 40.3 | 49.5 | 945 | 46.78 | 56.20 | 3.7 | 53.40 | 2.7 | 50.75 | 1.6 |
| 32 | 92.6 | 39.8 | 52.8 | 1,092 | 57.66 | 67.00 | 3.0 | 64.40 | 2.2 | 61.60 | 1.3 |

Table 3.--Rate of value increase of white oaks, by log height, grade, diameter, and vigor class

| Diam. breast high (inches) (1) | Per M board feet: Gross lumber value (2) | Direct costs (3) | Conversion surplus (4) | Lumber per tree (5) | Conversion surplus per tree by vigor class: Now (6) | High vigor: After 5 yrs. (7) | High vigor: Annual increase (8) | Medium vigor: After 5 yrs. (9) | Medium vigor: Annual increase (10) | Low vigor: After 5 yrs. (11) | Low vigor: Annual increase (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | | | Bd. ft. | Index | | Percent | Index | Percent | Index | Percent |
| | | | | 1-LOG-TREES, GRADE 1 | | | | | | | |
| 18 | 95.5 | 58.7 | 36.8 | 112 | 4.12 | 5.59 | 6.3 | 5.19 | 4.7 | 4.86 | 3.4 |
| 20 | 98.5 | 53.5 | 45.0 | 141 | 6.34 | 8.09 | 5.0 | 7.57 | 3.6 | 7.25 | 2.7 |
| 22 | 101.5 | 49.0 | 52.5 | 174 | 9.14 | 11.24 | 4.2 | 10.52 | 2.8 | 10.10 | 2.0 |
| 24 | 104.4 | 44.9 | 59.5 | 209 | 12.44 | 14.81 | 3.5 | 14.07 | 2.5 | 13.62 | 1.8 |
| 26 | 107.2 | 41.7 | 65.5 | 248 | 16.24 | 18.82 | 3.0 | 18.02 | 2.1 | 17.52 | 1.5 |
| 28 | 109.8 | 39.3 | 70.5 | 289 | 20.37 | 23.19 | 2.6 | 22.33 | 1.8 | 21.75 | 1.3 |
| 30 | 112.2 | 37.7 | 74.5 | 334 | 24.88 | 27.75 | 2.2 | 26.79 | 1.5 | 26.24 | 1.1 |
| 32 | 114.6 | 37.2 | 77.4 | 382 | 29.57 | 32.50 | 1.9 | 31.58 | 1.3 | 31.03 | 1.0 |
| | | | | GRADE 2 | | | | | | | |
| 16 | 67.2 | 64.1 | 3.1 | 86 | .27 | 1.10 | 32.3 | .81 | 24.6 | .71 | 21.3 |
| 18 | 70.7 | 58.7 | 12.0 | 112 | 1.34 | 2.45 | 12.9 | 2.18 | 10.2 | 2.00 | 8.3 |
| 20 | 74.1 | 53.5 | 20.6 | 141 | 2.90 | 4.15 | 7.4 | 3.75 | 5.3 | 3.50 | 3.8 |
| 22 | 77.6 | 49.0 | 28.6 | 174 | 4.98 | 6.49 | 5.4 | 5.98 | 3.7 | 5.65 | 2.6 |
| 24 | 80.8 | 44.9 | 35.9 | 209 | 7.50 | 9.32 | 4.4 | 8.76 | 3.2 | 8.45 | 2.4 |
| 26 | 84.0 | 41.7 | 42.3 | 248 | 10.49 | 12.50 | 3.6 | 11.92 | 2.6 | 11.50 | 1.9 |
| 28 | 87.0 | 39.3 | 47.7 | 289 | 13.79 | 16.09 | 3.1 | 15.32 | 2.1 | 14.95 | 1.6 |
| 30 | 89.8 | 37.7 | 52.1 | 334 | 17.40 | 19.57 | 2.4 | 18.87 | 1.6 | 18.50 | 1.2 |
| 32 | 92.0 | 37.2 | 54.8 | 382 | 20.93 | 22.92 | 1.8 | 22.04 | 1.0 | 21.85 | 0.9 |
| | | | | GRADE 3 | | | | | | | |
| 20 | 55.8 | 53.5 | 2.3 | 141 | .32 | .95 | 24.3 | .73 | 17.9 | .50 | 9.3 |
| 22 | 56.7 | 49.0 | 7.7 | 174 | 1.34 | 2.17 | 10.1 | 1.87 | 6.9 | 1.73 | 5.2 |
| 24 | 57.8 | 44.9 | 12.9 | 209 | 2.70 | 3.67 | 6.3 | 3.32 | 4.2 | 3.15 | 3.1 |
| 26 | 58.9 | 41.7 | 17.2 | 248 | 4.27 | 5.32 | 4.5 | 5.00 | 3.2 | 4.79 | 2.3 |
| 28 | 60.1 | 39.3 | 20.8 | 289 | 6.01 | 7.25 | 3.8 | 6.89 | 2.8 | 6.59 | 1.9 |
| 30 | 61.4 | 37.7 | 23.7 | 334 | 7.92 | 9.02 | 2.6 | 8.73 | 2.0 | 8.50 | 1.4 |
| 32 | 62.9 | 37.2 | 25.7 | 382 | 9.82 | 10.80 | 1.9 | 10.50 | 1.3 | 10.25 | 0.9 |
| | | | | 2-LOG-TREES, GRADE 1-2 | | | | | | | |
| 18 | 82.8 | 56.5 | 26.3 | 210 | 5.52 | 7.82 | 7.2 | 7.18 | 5.4 | 6.73 | 4.0 |
| 20 | 86.2 | 51.8 | 34.4 | 266 | 9.15 | 12.07 | 5.7 | 11.09 | 3.9 | 10.50 | 2.8 |
| 22 | 89.6 | 47.7 | 41.9 | 331 | 13.87 | 17.26 | 4.5 | 16.23 | 3.2 | 15.52 | 2.3 |
| 24 | 92.9 | 44.1 | 48.8 | 397 | 19.37 | 23.70 | 4.1 | 22.32 | 2.9 | 21.50 | 2.1 |
| 26 | 96.1 | 40.8 | 55.3 | 475 | 26.27 | 30.77 | 3.2 | 29.46 | 2.3 | 28.50 | 1.6 |
| 28 | 99.1 | 38.6 | 60.5 | 554 | 33.52 | 38.76 | 2.9 | 37.23 | 2.1 | 36.15 | 1.5 |
| 30 | 102.0 | 37.0 | 65.0 | 646 | 41.99 | 47.57 | 2.5 | 45.85 | 1.8 | 44.74 | 1.3 |
| 32 | 104.7 | 36.2 | 68.5 | 743 | 50.90 | 56.35 | 2.1 | 54.70 | 1.4 | 53.57 | 1.0 |
| | | | | GRADE 1-3 | | | | | | | |
| 18 | 72.1 | 56.5 | 15.6 | 210 | 3.28 | 5.25 | 9.9 | 4.73 | 7.6 | 4.32 | 5.7 |
| 20 | 76.0 | 51.8 | 24.2 | 266 | 6.44 | 9.00 | 6.9 | 8.21 | 5.0 | 7.65 | 3.5 |
| 22 | 80.0 | 47.7 | 32.3 | 331 | 10.69 | 13.75 | 5.1 | 12.73 | 3.5 | 12.18 | 2.7 |
| 24 | 83.8 | 44.1 | 39.7 | 397 | 15.76 | 19.75 | 4.6 | 18.50 | 3.2 | 17.70 | 2.4 |
| 26 | 87.6 | 40.8 | 46.8 | 475 | 22.23 | 26.50 | 3.6 | 25.09 | 2.4 | 24.27 | 1.8 |
| 28 | 91.2 | 38.6 | 52.6 | 554 | 29.14 | 34.07 | 3.2 | 32.53 | 2.2 | 31.56 | 1.6 |
| 30 | 94.6 | 37.0 | 57.6 | 646 | 37.21 | 42.36 | 2.6 | 40.67 | 1.8 | 39.68 | 1.3 |
| 32 | 97.6 | 36.2 | 61.4 | 743 | 45.62 | 50.57 | 2.1 | 49.07 | 1.5 | 48.03 | 1.0 |

Table 3.--(Continued)

| Diam. breast high (inches) (1) | Per M board feet: Gross lumber value (2) | Direct costs (3) | Conversion surplus (4) | Lumber per tree (5) | Conversion surplus per tree by vigor class: Now (6) | High vigor: After 5 yrs. (7) | High vigor: Annual increase (8) | Medium vigor: After 5 yrs. (9) | Medium vigor: Annual increase (10) | Low vigor: After 5 yrs. (11) | Low vigor: Annual increase (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | Index | Index | Bd. ft. | Index | Index | Percent | Index | Percent | Index | Percent |
| | | | | | GRADE 2-3 | | | | | | |
| 18 | 63.3 | 56.5 | 6.8 | 210 | 1.43 | 2.95 | 15.6 | 2.49 | 11.7 | 2.23 | 9.3 |
| 20 | 66.2 | 51.8 | 14.4 | 266 | 3.83 | 5.80 | 8.6 | 5.18 | 6.2 | 4.78 | 4.5 |
| 22 | 69.0 | 47.7 | 21.3 | 331 | 7.05 | 9.48 | 7.6 | 8.70 | 4.3 | 8.25 | 3.2 |
| 24 | 71.8 | 44.1 | 27.7 | 397 | 11.00 | 14.00 | 4.9 | 13.03 | 3.4 | 12.50 | 2.6 |
| 26 | 74.4 | 40.8 | 33.6 | 475 | 15.96 | 19.27 | 3.8 | 18.23 | 2.7 | 17.55 | 1.9 |
| 28 | 76.9 | 38.6 | 38.3 | 554 | 21.22 | 25.00 | 3.3 | 23.82 | 2.3 | 23.08 | 1.7 |
| 30 | 79.2 | 37.0 | 42.2 | 646 | 27.26 | 31.08 | 2.7 | 29.85 | 1.8 | 29.17 | 1.4 |
| 32 | 81.1 | 36.2 | 44.9 | 743 | 33.36 | 36.76 | 2.0 | 35.75 | 1.4 | 35.05 | 1.0 |
| | | | | | GRADE 3-3 | | | | | | |
| 20 | 53.6 | 51.8 | 1.8 | 266 | .48 | 1.50 | 25.5 | 1.20 | 20.1 | .97 | 15.1 |
| 22 | 54.5 | 47.7 | 6.8 | 331 | 2.25 | 3.57 | 9.7 | 3.22 | 7.4 | 2.85 | 4.8 |
| 24 | 55.4 | 44.1 | 11.3 | 397 | 4.49 | 6.25 | 6.8 | 5.71 | 4.9 | 5.28 | 3.3 |
| 26 | 56.4 | 40.8 | 15.6 | 475 | 7.41 | 9.28 | 4.6 | 8.73 | 3.3 | 8.32 | 2.3 |
| 28 | 57.6 | 38.6 | 19.0 | 554 | 10.53 | 12.72 | 3.8 | 12.04 | 2.7 | 11.55 | 1.9 |
| 30 | 58.8 | 37.0 | 21.8 | 646 | 14.08 | 16.42 | 3.1 | 15.65 | 2.1 | 15.20 | 1.5 |
| 32 | 60.1 | 36.2 | 23.9 | 743 | 17.76 | 20.03 | 2.4 | 19.41 | 1.8 | 18.92 | 1.3 |
| | | | | | 3-LOG-TREES, GRADE 1-1-2 | | | | | | |
| 22 | 94.3 | 45.5 | 48.8 | 475 | 23.18 | 28.48 | 4.2 | 26.74 | 2.9 | 25.72 | 2.1 |
| 24 | 97.3 | 42.5 | 54.8 | 580 | 31.78 | 37.75 | 3.5 | 35.97 | 2.5 | 34.74 | 1.8 |
| 26 | 100.2 | 39.8 | 60.4 | 690 | 41.68 | 48.75 | 3.2 | 46.45 | 2.2 | 45.05 | 1.6 |
| 28 | 103.0 | 37.8 | 65.2 | 814 | 53.07 | 60.77 | 2.8 | 58.38 | 1.9 | 56.87 | 1.4 |
| 30 | 105.8 | 36.4 | 69.4 | 945 | 65.58 | 73.98 | 2.4 | 71.31 | 1.7 | 69.73 | 1.2 |
| 32 | 108.2 | 35.7 | 72.5 | 1,092 | 79.17 | 87.23 | 1.9 | 84.69 | 1.3 | 83.04 | 1.0 |
| | | | | | GRADE 1-1-3 | | | | | | |
| 22 | 87.4 | 45.5 | 41.9 | 475 | 19.90 | 24.98 | 4.7 | 23.30 | 3.2 | 22.35 | 2.4 |
| 24 | 90.8 | 42.5 | 48.3 | 580 | 28.01 | 33.76 | 3.8 | 31.95 | 2.7 | 30.78 | 1.9 |
| 26 | 94.0 | 39.8 | 54.2 | 690 | 37.40 | 44.19 | 3.4 | 42.00 | 2.3 | 40.73 | 1.7 |
| 28 | 97.1 | 37.8 | 59.3 | 814 | 48.27 | 55.49 | 2.8 | 53.23 | 2.0 | 51.75 | 1.4 |
| 30 | 100.0 | 36.4 | 63.6 | 945 | 60.10 | 68.23 | 2.6 | 65.54 | 1.7 | 63.98 | 1.3 |
| 32 | 102.8 | 35.7 | 67.1 | 1,092 | 73.27 | 80.74 | 2.0 | 78.30 | 1.3 | 76.82 | 0.9 |
| | | | | | GRADE 1-2-3 | | | | | | |
| 18 | 74.2 | 52.9 | 21.3 | 302 | 6.43 | 9.36 | 7.8 | 8.48 | 5.7 | 7.87 | 4.1 |
| 20 | 78.2 | 49.2 | 29.0 | 384 | 11.14 | 15.00 | 6.1 | 13.75 | 4.3 | 12.99 | 3.1 |
| 22 | 82.3 | 45.5 | 36.8 | 475 | 17.48 | 22.45 | 5.1 | 20.77 | 3.5 | 19.80 | 2.5 |
| 24 | 86.3 | 42.5 | 43.8 | 580 | 25.40 | 31.17 | 4.2 | 29.31 | 2.9 | 28.05 | 2.0 |
| 26 | 90.2 | 39.8 | 50.4 | 690 | 34.78 | 41.50 | 3.6 | 39.30 | 2.5 | 38.02 | 1.8 |
| 28 | 93.8 | 37.8 | 56.0 | 814 | 45.58 | 52.81 | 3.0 | 50.61 | 2.1 | 49.25 | 1.6 |
| 30 | 97.4 | 36.4 | 61.0 | 945 | 57.64 | 65.60 | 2.6 | 63.00 | 1.8 | 61.47 | 1.3 |
| 32 | 100.3 | 35.7 | 64.6 | 1,092 | 70.54 | 77.80 | 2.0 | 75.54 | 1.4 | 74.12 | 1.0 |

Table 4.--Rate of value increase of yellow-poplar, by log height, grade, diameter, and vigor class

| Diam. breast high (inches) (1) | Per M board feet: Gross lumber value (2) | Direct costs (3) | Conversion surplus (4) | Lumber per tree (5) | Conversion surplus per tree by vigor class: Now (6) | High vigor: After 5 yrs. (7) | High vigor: Annual increase (8) | Medium vigor: After 5 yrs. (9) | Medium vigor: Annual increase (10) | Low vigor: After 5 yrs. (11) | Low vigor: Annual increase (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | | | Bd. ft. | Index | | Percent | Index | Percent | Index | Percent |
| | | | | | 1-LOG-TREES, GRADE 1 | | | | | | |
| 18 | 99.2 | 51.5 | 47.7 | 112 | 5.34 | 7.68 | 7.5 | 7.05 | 5.7 | 6.50 | 4.0 |
| 20 | 100.7 | 46.2 | 54.5 | 141 | 7.68 | 10.39 | 6.2 | 9.65 | 4.7 | 9.00 | 3.2 |
| 22 | 102.0 | 42.3 | 59.7 | 174 | 10.39 | 13.38 | 5.2 | 12.55 | 3.8 | 11.80 | 2.6 |
| 24 | 103.4 | 39.4 | 64.0 | 209 | 13.38 | 16.72 | 4.6 | 15.85 | 3.4 | 15.00 | 2.3 |
| 26 | 104.6 | 37.2 | 67.4 | 248 | 16.72 | 20.26 | 3.9 | 19.40 | 3.0 | 18.50 | 2.0 |
| 28 | 105.7 | 35.6 | 70.1 | 289 | 20.26 | 24.01 | 3.5 | 23.10 | 2.7 | 22.20 | 1.8 |
| 30 | 106.6 | 34.7 | 71.9 | 334 | 24.01 | 27.89 | 3.0 | 26.95 | 2.3 | 26.00 | 1.6 |
| 32 | 107.5 | 34.5 | 73.0 | 382 | 27.89 | 31.60 | 2.5 | 30.65 | 1.9 | 29.80 | 1.3 |
| | | | | | GRADE 2 | | | | | | |
| 16 | 77.6 | 59.1 | 18.5 | 86 | 1.59 | 3.00 | 13.6 | 2.60 | 10.4 | 2.20 | 6.7 |
| 18 | 78.3 | 51.5 | 26.8 | 112 | 3.00 | 4.64 | 9.1 | 4.25 | 7.2 | 3.85 | 5.1 |
| 20 | 79.1 | 46.2 | 32.9 | 141 | 4.64 | 6.52 | 7.0 | 6.00 | 5.3 | 5.60 | 3.8 |
| 22 | 79.8 | 42.3 | 37.5 | 174 | 6.52 | 8.57 | 5.6 | 8.00 | 4.2 | 7.45 | 2.7 |
| 24 | 80.4 | 39.4 | 41.0 | 209 | 8.57 | 10.89 | 4.9 | 10.25 | 3.6 | 9.70 | 2.5 |
| 26 | 81.1 | 37.2 | 43.9 | 248 | 10.89 | 13.32 | 4.1 | 12.65 | 3.0 | 12.05 | 2.0 |
| 28 | 81.7 | 35.6 | 46.1 | 289 | 13.32 | 15.86 | 3.5 | 15.20 | 2.7 | 14.60 | 1.9 |
| 30 | 82.2 | 34.7 | 47.5 | 334 | 15.86 | 18.34 | 2.9 | 17.70 | 2.2 | 17.05 | 1.5 |
| 32 | 82.5 | 34.5 | 48.0 | 382 | 18.34 | 20.60 | 2.4 | 20.05 | 1.8 | 19.50 | 1.2 |
| | | | | | GRADE 3 | | | | | | |
| 16 | 68.0 | 59.1 | 8.9 | 86 | .77 | 1.92 | 20.0 | 1.65 | 16.4 | 1.35 | 11.9 |
| 18 | 68.6 | 51.5 | 17.1 | 112 | 1.92 | 3.29 | 11.3 | 3.00 | 9.3 | 2.60 | 6.3 |
| 20 | 69.5 | 46.2 | 23.3 | 141 | 3.29 | 4.84 | 8.0 | 4.45 | 6.2 | 4.05 | 4.3 |
| 22 | 70.1 | 42.3 | 27.8 | 174 | 4.84 | 6.54 | 6.2 | 6.10 | 4.7 | 5.65 | 3.1 |
| 24 | 70.7 | 39.4 | 31.3 | 209 | 6.54 | 8.43 | 5.2 | 7.95 | 4.0 | 7.50 | 2.8 |
| 26 | 71.2 | 37.2 | 34.0 | 248 | 8.43 | 10.38 | 4.3 | 9.90 | 3.3 | 9.40 | 2.2 |
| 28 | 71.5 | 35.6 | 35.9 | 289 | 10.38 | 12.36 | 3.5 | 11.85 | 2.7 | 11.35 | 1.8 |
| 30 | 71.7 | 34.7 | 37.0 | 334 | 12.36 | 14.25 | 2.9 | 13.80 | 2.2 | 13.30 | 1.5 |
| 32 | 71.8 | 34.5 | 37.3 | 382 | 14.25 | 16.05 | 2.4 | 15.65 | 1.9 | 15.20 | 1.3 |
| | | | | | 2-LOG-TREES, GRADE 1-2 | | | | | | |
| 18 | 90.7 | 50.0 | 40.7 | 210 | 8.55 | 12.37 | 7.7 | 11.35 | 5.8 | 10.40 | 4.0 |
| 20 | 91.7 | 45.2 | 46.5 | 266 | 12.37 | 16.91 | 6.4 | 15.75 | 5.0 | 14.60 | 3.4 |
| 22 | 92.6 | 41.5 | 51.1 | 331 | 16.91 | 21.80 | 5.2 | 20.60 | 4.0 | 19.40 | 2.8 |
| 24 | 93.6 | 38.7 | 54.9 | 397 | 21.80 | 27.50 | 4.8 | 26.10 | 3.7 | 24.65 | 2.5 |
| 26 | 94.4 | 36.5 | 57.9 | 475 | 27.50 | 33.30 | 3.9 | 31.80 | 2.9 | 30.40 | 2.0 |
| 28 | 95.1 | 35.0 | 60.1 | 554 | 33.30 | 39.86 | 3.6 | 38.20 | 2.8 | 36.60 | 1.9 |
| 30 | 95.7 | 34.0 | 61.7 | 646 | 39.86 | 46.21 | 3.0 | 44.60 | 2.3 | 43.00 | 1.5 |
| 32 | 96.1 | 33.9 | 62.2 | 743 | 46.21 | 52.40 | 2.5 | 50.85 | 1.9 | 49.40 | 1.3 |
| | | | | | GRADE 1-3 | | | | | | |
| 18 | 82.4 | 50.0 | 32.4 | 210 | 6.80 | 10.21 | 8.5 | 9.40 | 6.7 | 8.50 | 4.6 |
| 20 | 83.6 | 45.2 | 38.4 | 266 | 10.21 | 14.27 | 6.9 | 13.20 | 5.3 | 12.20 | 3.6 |
| 22 | 84.6 | 41.5 | 43.1 | 331 | 14.27 | 18.62 | 5.5 | 17.60 | 4.3 | 16.40 | 2.8 |
| 24 | 85.6 | 38.7 | 46.9 | 397 | 18.62 | 23.70 | 4.9 | 22.35 | 3.7 | 21.15 | 2.6 |
| 26 | 86.4 | 36.5 | 49.9 | 475 | 23.70 | 28.92 | 4.1 | 27.60 | 3.1 | 26.25 | 2.1 |
| 28 | 87.2 | 35.0 | 52.2 | 554 | 28.92 | 34.82 | 3.8 | 33.30 | 2.9 | 31.80 | 1.9 |
| 30 | 87.9 | 34.0 | 53.9 | 646 | 34.82 | 40.49 | 3.1 | 39.08 | 2.3 | 37.65 | 1.6 |
| 32 | 88.4 | 33.9 | 54.5 | 743 | 40.49 | 46.10 | 2.6 | 44.75 | 2.0 | 43.30 | 1.3 |

Table 4.--(Continued)

| Diam. breast high (inches) (1) | Per M board feet: Gross lumber value (2) | Direct costs (3) | Conversion surplus (4) | Lumber per tree (5) | Conversion surplus per tree by vigor class: Now (6) | High vigor: After 5 yrs. (7) | High vigor: Annual increase (8) | Medium vigor: After 5 yrs. (9) | Medium vigor: Annual increase (10) | Low vigor: After 5 yrs. (11) | Low vigor: Annual increase (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | | | Bd. ft. | Index | | Percent | Index | Percent | Index | Percent |
| | | | | | GRADE 2-3 | | | | | | |
| 16 | 72.3 | 56.7 | 15.6 | 162 | 2.53 | 4.87 | 14.0 | 4.30 | 11.1 | 3.75 | 8.2 |
| 18 | 73.2 | 50.0 | 23.2 | 210 | 4.87 | 7.71 | 9.6 | 7.00 | 7.5 | 6.30 | 5.3 |
| 20 | 74.2 | 45.2 | 29.0 | 266 | 7.71 | 11.09 | 7.5 | 10.10 | 5.5 | 9.40 | 4.0 |
| 22 | 75.0 | 41.5 | 33.5 | 331 | 11.09 | 14.73 | 5.8 | 13.80 | 4.5 | 12.85 | 3.0 |
| 24 | 75.8 | 38.7 | 37.1 | 397 | 14.73 | 18.95 | 5.2 | 17.90 | 4.0 | 16.80 | 2.7 |
| 26 | 76.4 | 36.5 | 39.9 | 475 | 18.95 | 23.16 | 4.1 | 22.00 | 3.0 | 21.00 | 2.1 |
| 28 | 76.8 | 35.0 | 41.8 | 554 | 23.16 | 27.91 | 3.8 | 26.75 | 2.9 | 25.55 | 2.0 |
| 30 | 77.2 | 34.0 | 43.2 | 646 | 27.91 | 32.32 | 3.0 | 31.20 | 2.2 | 30.10 | 1.5 |
| 32 | 77.4 | 33.9 | 43.5 | 743 | 32.32 | 36.70 | 2.6 | 35.65 | 2.0 | 34.60 | 1.4 |
| | | | | | GRADE 3-3 | | | | | | |
| 16 | 64.7 | 56.7 | 8.0 | 162 | 1.30 | 3.21 | 19.8 | 2.75 | 16.2 | 2.20 | 11.0 |
| 18 | 65.3 | 50.0 | 15.3 | 210 | 3.21 | 5.48 | 11.3 | 4.85 | 8.6 | 4.30 | 6.0 |
| 20 | 65.8 | 45.2 | 20.6 | 266 | 5.48 | 8.18 | 8.3 | 7.45 | 6.3 | 6.80 | 4.4 |
| 22 | 66.2 | 41.5 | 24.7 | 331 | 8.18 | 11.04 | 6.2 | 10.27 | 4.6 | 9.60 | 3.3 |
| 24 | 66.5 | 38.7 | 27.8 | 397 | 11.04 | 14.34 | 5.4 | 13.45 | 4.0 | 12.65 | 2.8 |
| 26 | 66.7 | 36.5 | 30.2 | 475 | 14.34 | 17.62 | 4.2 | 16.80 | 3.2 | 16.00 | 2.2 |
| 28 | 66.8 | 35.0 | 31.8 | 554 | 17.62 | 21.25 | 3.8 | 20.35 | 2.9 | 19.50 | 2.0 |
| 30 | 66.9 | 34.0 | 32.9 | 646 | 21.25 | 24.59 | 3.0 | 23.75 | 2.2 | 22.90 | 1.5 |
| 32 | 67.0 | 33.9 | 33.1 | 743 | 24.59 | 27.80 | 2.5 | 27.00 | 1.9 | 26.20 | 1.3 |
| | | | | | 3-LOG-TREES, GRADE 1-1-2 | | | | | | |
| 22 | 96.8 | 41.0 | 55.8 | 475 | 26.50 | 34.45 | 5.4 | 32.40 | 4.1 | 30.40 | 2.8 |
| 24 | 97.7 | 38.3 | 59.4 | 580 | 34.35 | 42.99 | 4.5 | 40.80 | 3.4 | 38.75 | 2.4 |
| 26 | 98.5 | 36.2 | 62.3 | 690 | 42.99 | 52.42 | 4.0 | 50.00 | 3.1 | 47.75 | 2.1 |
| 28 | 99.2 | 34.8 | 64.4 | 814 | 52.42 | 62.75 | 3.7 | 60.05 | 2.8 | 57.50 | 1.9 |
| 30 | 99.9 | 33.5 | 66.4 | 945 | 62.75 | 73.05 | 3.1 | 70.35 | 2.3 | 67.80 | 1.6 |
| 32 | 100.3 | 33.4 | 66.9 | 1,092 | 73.05 | 81.82 | 2.3 | 79.70 | 1.8 | 77.43 | 1.2 |
| | | | | | GRADE 1-1-3 | | | | | | |
| 22 | 90.4 | 41.0 | 49.4 | 475 | 23.46 | 30.74 | 5.6 | 28.90 | 4.3 | 27.05 | 2.9 |
| 24 | 91.3 | 38.3 | 53.0 | 580 | 30.74 | 38.57 | 4.6 | 36.50 | 3.5 | 34.60 | 2.4 |
| 26 | 92.1 | 36.2 | 55.9 | 690 | 38.57 | 47.29 | 4.2 | 45.00 | 3.1 | 42.85 | 2.1 |
| 28 | 92.9 | 34.8 | 58.1 | 814 | 47.29 | 56.70 | 3.7 | 54.20 | 2.8 | 51.85 | 1.9 |
| 30 | 93.5 | 33.5 | 60.0 | 945 | 56.70 | 66.18 | 3.1 | 63.75 | 2.4 | 61.30 | 1.6 |
| 32 | 94.0 | 33.4 | 60.6 | 1,092 | 66.18 | 74.60 | 2.4 | 72.60 | 1.9 | 70.55 | 1.3 |
| | | | | | GRADE 1-2-3 | | | | | | |
| 18 | 83.5 | 49.0 | 34.5 | 302 | 10.42 | 15.44 | 8.2 | 14.20 | 6.4 | 13.00 | 4.5 |
| 20 | 84.6 | 44.4 | 40.2 | 384 | 15.44 | 21.23 | 6.6 | 19.80 | 5.1 | 18.30 | 3.5 |
| 22 | 85.7 | 41.0 | 44.7 | 475 | 21.23 | 28.07 | 5.7 | 26.35 | 4.4 | 24.60 | 3.0 |
| 24 | 86.7 | 38.3 | 48.4 | 580 | 28.07 | 35.47 | 4.8 | 33.60 | 3.7 | 31.75 | 2.5 |
| 26 | 87.6 | 36.2 | 51.4 | 690 | 35.47 | 43.63 | 4.2 | 41.60 | 3.2 | 39.60 | 2.2 |
| 28 | 88.4 | 34.8 | 53.6 | 814 | 43.63 | 52.54 | 3.8 | 50.20 | 2.8 | 48.00 | 1.9 |
| 30 | 89.1 | 33.5 | 55.6 | 945 | 52.54 | 61.37 | 3.1 | 59.05 | 2.4 | 56.85 | 1.6 |
| 32 | 89.6 | 33.4 | 56.2 | 1,092 | 61.37 | 69.00 | 2.4 | 67.15 | 1.8 | 65.25 | 1.2 |

tree (column 6) was determined, and, following this (columns 7, 9, and 11), the prospective conversion surplus per tree after 5 years for each vigor class (growth rate), assuming no change in log height or grade. The ratio of value after 5 years to value now was computed, after which compound-interest tables were used to find the annual percentage increase (columns 8, 10, and 12).

As an example of the use of tables 2, 3, and 4, take the problem of a forest manager who is deciding whether to mark a 28-inch yellow-poplar, grade 1-2, high vigor--or whether to let it grow for another 5 years. Large limbs above the second log permanently limit the merchantable height, nor is the grade of either log likely to improve soon. The rate of return that the manager follows as his guide is 4 percent. Table 4 indicates that the yellow-poplar will earn less than this rate--only 3.6 percent--in the coming 5 years. It is therefore financially mature and should be marked for cutting.

Changes in height and grade.--Both log height and grade normally change as a tree grows in diameter. Limbs die and fall off, and clear wood covers the knots. Butt logs of small trees are subject to radical improvement in grade once the limbs are dropped because of the increasing thickness of clear wood deposited over the heart center. The same thing happens, though to a lesser degree, to upper logs. Furthermore, for reasons explained by the log grades already referred to, logs may improve in grade merely with increase in diameter. In the upper bole, additional logs are created as girth is added to meet minimum size specifications and as the bole clears enough to meet quality specifications. Thus small, short hardwoods of low grade are often capable of developing into 2- and 3-log, high-grade trees. Though many exceptions are found, especially in upper logs, most of the potential rapid improvement in grade has been realized by the time a hardwood tree reaches 24 or 26 inches d.b.h. Large hardwoods usually have their log height firmly established by the position and form of the crown. Imminent and potential changes in log height and grade can, with experience, be recognized by the forester or woodsman, and to recognize them is essential in determining financial maturity.

Tables 2, 3, and 4 may be used for calculating (though not reading directly) the rate of value increase for trees expected to grow in log height or to improve in grade. Suppose that our 28-inch, grade 1-2 yellow-poplar is expected to add a third log in the coming 5 years, so as to become a 30-inch, grade 1-2-3 tree. Table 4 shows that the value now is index 33.30, and that the value in 5 years (reading in the same column, opposite the expected grade and diameter) will be index 52.54. A calculation of the ratio of these indexes and reference to compound interest tables discloses that the rate of increase is 9.5 percent. If a 4-percent return is satisfactory, the tree is not yet mature.

Prospective increases in both grade and height may be evaluated in the same way. If the grade 1-2 yellow-poplar grows to grade 1-1-3 in 5 years, the rate of value increase will be even higher, 11.1 percent.

Table 5 (column 2), shows the probable course of grade development for a high-vigor and potentially high-grade red oak that grows from 18 to 28 inches d.b.h. As the tree goes from 18 to 22 inches, both logs will improve in grade. At 24 inches, the tree develops a third log and continues to improve in grade as it grows to 28 inches. Column 3 shows the rate of conversion surplus increase for a tree with this grade and height development. Column 4 shows the rates of value increase if there are no height and grade changes. The contrast between columns 3 and 4 indicates that any red oak tree near the borderline of financial maturity should be kept for additional growth if it promises to extend its log height or improve its grade; the same is true for white oaks and yellow-poplar.

Table 5.--Rate of value increase of high-grade, high-vigor red oaks, with and without log height and grade changes

| Tree d.b.h. (inches) | Tree grade | Annual conversion-surplus increase | |
|---|---|---|---|
| | | With height and grade changes | Without height and grade changes |
| (1) | (2) | (3) | (4) |
| | | Percent | |
| 18 | 2-3 | 54.7 | 33.6 |
| 20 | 1-3 | 14.5 | 9.3 |
| 22 | 1-2 | 8.1 | 5.4 |
| 24 | 1-2-3 | 6.8 | 5.2 |
| 26 | 1-1-3 | 5.0 | 4.1 |
| 28 | 1-1-2 | ... | 3.7 |

At this point the reader may well ask, what about the competition between the tree in question and other trees? And how does the system provide for secondary products like cross ties and mine props? Before these two questions can be answered, it will be necessary to tabulate the rate of tree value increase in terms of ties and props.

## Cross Ties

Currently, well over 90 percent of the standard grade-5 (measuring 7 inches by 9 inches by 8½ feet) hardwood cross ties produced in the Birmingham district are sawn; of these, about 80 percent are cut from red and white oak species. A typical mill for hardwood cross-tie production will, in a representative day's run, produce 150 to 250 grade-5

ties. In addition, it will cut some 600 to 1,000 board feet of side lumber per 100 ties, the amount varying with the size and quality of the timber. Since side lumber is essential to a profitable tie operation, tree volume will be expressed in board feet of ties and side lumber.

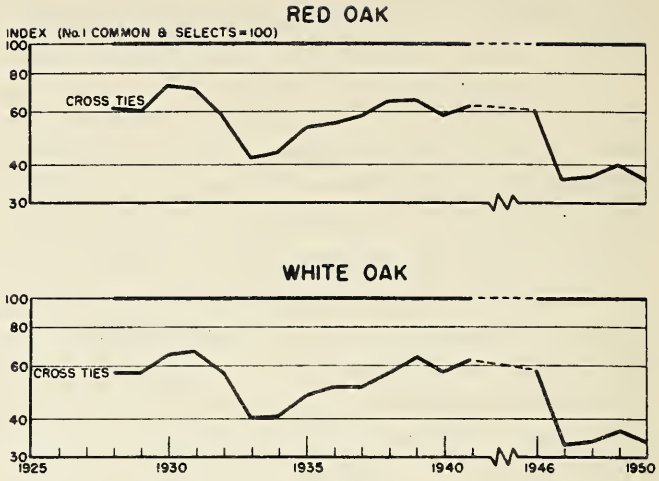


Figure 6.--Cross-tie values per M as a percent of the value of No. 1 Common and Select lumber per M.

In a forest managed primarily for lumber logs, tie cutting will be restricted to those trees whose removal will expedite the production of lumber logs. A tie, considered by itself, can be cut from any sound timber. But since tie logs, on the average, must afford an adequate cut of side lumber, the following estimates of ties and side lumber are based on the average trees that the forest manager can be expected to channel into tie production.

In order to compare a tree's worth for standard factory lumber with its worth for cross ties, a common unit of value must be used. In terms of the index values developed for lumber, it appears that over the years ties (per M board feet of lumber equivalent) are worth about 50 percent of the value of No. 1 Common and Selects (fig. 6). That is, their index value is 50. Side lumber usually sells for the same price as 3A Common. In terms of index values, this is 52 for red oak side lumber, and 49 for that of white oak. For convenience, index value 50 is used for both side lumber and cross ties. Table 6 shows the number of ties and the amount of side lumber per tree, and the conversion surpluses in terms of the lumber index. In addition, the annual increases for 5-year periods and the annual rates of conversion surplus increase are given for the three vigor classes.

## Mine Props

Mine props are procured on a custom basis. That is, they are ordered by specific sizes and quantities, to be delivered green at the mine head. Since the requirement of greenness precludes cutting and stocking large quantities of the sizes ordinarily demanded, prop production is a small-scale operation.

Table 6.--Cross-tie trees: rate of value increase, in terms of lumber index, by vigor class

| Diam. breast high (inches) | Grade 5 ties | Side lumber | Ties and lumber | Gross product value | Direct cost | Now | Conversion surplus per tree by vigor class: High vigor: After 5 yrs. | High vigor: Annual increase | Medium vigor: After 5 yrs. | Medium vigor: Annual increase | Low vigor: After 5 yrs. | Low vigor: Annual increase |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | B.f. per tree | | - Index per tree - | | | Index | Percent | Index | Percent | Index | Percent |
| | | | | | Red Oaks | | | | | | | |
| 12 | 1 | 3 | 48 | 2.40 | 2.29 | 0.11 | 0.83 | 49.8 | 0.63 | 41.5 | 0.43 | 25.5 |
| 13 | 1 1/2 | 6 | 73 | 3.65 | 3.10 | .55 | 1.18 | 16.4 | 1.00 | 12.7 | .83 | 8.6 |
| 14 | 2 | 11 | 101 | 5.05 | 4.15 | .90 | 1.50 | 10.7 | 1.35 | 8.4 | 1.18 | 5.6 |
| 15 | 2 1/2 | 27 | 139 | 6.95 | 5.70 | 1.25 | 1.71 | 6.4 | 1.62 | 5.3 | 1.50 | 3.7 |
| 16 | 2 3/4 | 33 | 157 | 7.85 | 6.28 | 1.57 | 1.87 | 3.6 | 1.80 | 2.8 | 1.71 | 1.7 |
| 17 | 3 | 50 | 185 | 9.25 | 7.50 | 1.75 | 1.99 | 2.6 | 1.94 | 2.1 | 1.87 | 1.3 |
| 18 | 3 1/4 | 63 | 209 | 10.45 | 8.55 | 1.90 | 2.07 | 1.7 | 2.04 | 1.4 | 1.99 | .9 |
| | | | | | White Oaks | | | | | | | |
| 12 | 1 | 3 | 48 | 2.40 | 2.29 | .11 | .63 | 41.5 | .47 | 33.7 | .37 | 27.3 |
| 13 | 1 1/2 | 6 | 73 | 3.65 | 3.10 | .55 | 1.00 | 12.7 | .87 | 9.6 | .78 | 7.2 |
| 14 | 2 | 11 | 101 | 5.05 | 4.15 | .90 | 1.35 | 8.4 | 1.22 | 6.3 | 1.13 | 4.7 |
| 15 | 2 1/2 | 27 | 139 | 6.95 | 5.70 | 1.25 | 1.62 | 5.3 | 1.53 | 4.1 | 1.46 | 3.1 |
| 16 | 2 3/4 | 33 | 157 | 7.85 | 6.28 | 1.57 | 1.80 | 2.8 | 1.73 | 2.0 | 1.69 | 1.5 |
| 17 | 3 | 50 | 185 | 9.25 | 7.50 | 1.75 | 1.94 | 2.1 | 1.89 | 1.5 | 1.85 | 1.1 |
| 18 | 3 1/4 | 63 | 209 | 10.45 | 8.55 | 1.90 | 2.04 | 1.4 | 2.00 | 1.0 | 1.98 | .8 |

Table 7.--Prop trees: rate of value increase, in terms of lumber index, by vigor class

| Diam. breast high (inches) | 5-foot props | Gross product value | Direct cost | Now | Conversion surplus per tree by vigor class: High vigor: After 5 yrs. | High vigor: Annual increase | Medium vigor: After 5 yrs. | Medium vigor: Annual increase | Low vigor: After 5 yrs. | Low vigor: Annual increase |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | - - Index per tree - - | | | Index | Percent | Index | Percent | Index | Percent |
| | | | | Red Oaks | | | | | | |
| 6 | 2.0 | 0.33 | 0.28 | 0.05 | 0.21 | 33.1 | 0.17 | 27.5 | 0.13 | 20.8 |
| 7 | 3.0 | .50 | .34 | .16 | .28 | 11.9 | .25 | 9.5 | .22 | 6.6 |
| 8 | 3.8 | .63 | .39 | .24 | .32 | 5.9 | .31 | 5.2 | .28 | 3.1 |
| 9 | 4.4 | .73 | .44 | .29 | .35 | 3.8 | .34 | 3.2 | .32 | 2.0 |
| 10 | 5.4 | .89 | .56 | .33 | .38 | 2.9 | .37 | 2.3 | .35 | 1.2 |
| 11 | 6.2 | 1.02 | .66 | .36 | .39 | 1.6 | .38 | 1.1 | .37 | .6 |
| | | | | White Oaks | | | | | | |
| 6 | 2.0 | .32 | .27 | .05 | .16 | 26.1 | .13 | 21.0 | .10 | 14.9 |
| 7 | 3.0 | .47 | .33 | .14 | .24 | 11.3 | .21 | 8.5 | .19 | 6.2 |
| 8 | 3.8 | .60 | .37 | .23 | .29 | 4.7 | .27 | 3.3 | .26 | 2.5 |
| 9 | 4.4 | .70 | .42 | .28 | .33 | 3.3 | .32 | 2.7 | .31 | 2.1 |
| 10 | 5.4 | .85 | .54 | .31 | .35 | 2.4 | .34 | 1.9 | .33 | 1.3 |
| 11 | 6.2 | .98 | .63 | .35 | .37 | 1.1 | .36 | .6 | .35 | .0 |

Producers usually operate in trees ranging from 5 to 11 inches d.b.h. The most common size of prop is 5 feet long. Tree quality is relatively unimportant save for the straightness and soundness of the lengths cut.10/

While hardwood props have come into use in the Birmingham territory only in recent years, the current relation of prop trees to lumber-log and cross-tie trees may be assumed to hold for the near future. Sales values and direct costs of producing props have been worked out in dollars per tree and then converted to lumber index values per tree. Thus comparisons can be made, tree by tree, between the alternatives of standard factory lumber, cross ties, and mine props. Table 7 shows the number of 5-foot props, conversion surpluses per tree, and the annual rates of conversion surplus increase for the three vigor classes.

## Effect of Other Trees

In judging financial maturity one cannot, of course, consider a tree solely on its own merits. Every forest tree is in more or less competition with other trees, and this competition affects the desirability of the tree as an investment. Some trees which, judged alone, are apparently financially mature, turn out not to be mature when one or more other trees are brought into consideration. Likewise trees may prove to be mature which considered by themselves were not so. The principle covering the effect of other trees upon financial maturity is this: the aim of the manager should be to maintain on each acre that volume of timber which, within the requirements of the silvicultural system and the program of regulation, has the greatest possible conversion surplus in trees not yet financially mature. For reasons made clear in the reference cited in footnote 1, following this principle will result in securing, from each acre, the highest income that the desired rate of return will afford.

Therefore, where two competing trees both appear to be mature but where removal of one would raise the vigor of the other sufficiently to make it no longer mature, a general rule is to retain that tree for growth which has the higher value now or prospectively--the greater size or higher grade, or the better chance of increasing its size or improving its grade. The other tree should be cut.

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10/. Osborn, R. M. Costs of producing mine props. South. Forest Expt. Sta., Occas. Paper 124, 22 pp., illus. 1951.

Griswold, N. B., and McKnight, J. S. Wood use by Alabama mines. South. Forest Expt. Sta., Occas. Paper 109, 12 pp., illus. 1947.

Take the case of two competing yellow-poplars. Both are of medium vigor, but if either is cut the vigor of the other will become high. Following are the pertinent data on these yellow-poplars, read from table 4:

| | Tree A | Tree B |
|---|---|---|
| Diameter breast high (inches) | 24 | 26 |
| Grade | 1-2 | 2-3 |
| Conversion surplus | 21.80 | 18.95 |
| Medium vigor: | | |
| Conversion surplus after 5 years | 26.10 | 22.00 |
| Rate of increase (percent) | 3.7 | 3.0 |
| High vigor: | | |
| Conversion surplus after 5 years | 27.50 | 23.16 |
| Rate of increase (percent) | 4.8 | 4.1 |

With a 4-percent desired rate of return, one of these trees is mature and should be cut, while the other should be left to grow one more cutting cycle. Since tree A, the 24-inch grade 1-2 yellow-poplar, has the higher value both now and prospectively, it should be left to grow.

A comparison of these alternative trees will show the reasoning behind the rule. For convenience, assume that conversion surplus equals dollars. Then the value added to the business over the next 5 years is:

| | Cutting tree A | Cutting tree B |
|---|---|---|
| Value of tree cut, invested at 4 percent compound, earns | 4.73 | 4.11 |
| Growth in value of tree left: | | |
| Tree A | ... | 5.70 |
| Tree B | 4.21 | ... |
| Total value added to the business | 8.94 | 9.81 |

Since cutting tree B will increase the worth of the business by 87 cents more than the alternative of cutting A, tree A should be left to grow. The rule is designed to cover the vast majority of the numerous alternatives facing the forest manager. There will be exceptions, but the virtue of the rule is that it obviates making separate calculations for every alternative that arises.

## The Maturity Dilemma

A glance at tables 2, 3, 6, and 7 will show that an oak may apparently mature at different stages in its development, depending on whether it is to be used for lumber, cross ties, or mine props. How can this be? Should not there be only one point of maturity for a given tree and a given rate of return? The answer is "yes." The principle to follow is that of electing maturity for the product that will afford the greatest amount of conversion surplus per unit of time and area for the desired rate of return.

This requires a judgment as to the number of prop trees or cross-tie trees that can be grown in the time and on the area needed to bring a tree to maturity for lumber logs. Following is a rough example of the kind of calculation necessary to resolve the dilemma of logs versus ties versus props.

Tables 2, 6, and 7 show that, where a 3-percent rate of return is desired, a medium-vigor red oak of potential grade 2-3 will mature for mine props at 9 inches d.b.h., at which time its index value will be 0.29. It will mature for cross ties at 15 inches d.b.h. (index value 1.25) and for saw timber at 30 inches (value 20.61). In the time needed to grow the tree (at medium vigor) to lumber-log maturity, about three crops of mine props can be raised, with perhaps 3 trees per crop. Similarly, about two crops of cross-tie trees could be matured, with 2 trees in each crop. Therefore:

| | |
|---|---|
| PROP TREE ALTERNATIVE | |
| Returns from first crop of props, invested at 3 percent compound interest . . . . . | 14.91 |
| Returns from second crop of prop trees, at 3 percent compound interest . . . . . | 3.60 |
| Final crop of mine props . . . . . | .87 |
| Total conversion surplus | 19.38 |
| TIE TREE ALTERNATIVE | |
| Returns from first crop of ties, invested at 3 percent compound . . . . . | 14.72 |
| Final crop of cross ties . . . . . | 2.50 |
| Total conversion surplus | 17.22 |
| SAWLOG TREE ALTERNATIVE . . . . . | 20.61 |

In this example, the sawlog tree is clearly the best alternative, even without consideration of prop- or cross-tie trees that could have been raised in conjunction with it. If either the prospective grade or the growth rate (vigor class) of the sawlog tree had been lower, however, mine props or ties would have been the better alternative. A higher rate of interest than 3 percent would also have called for higher grade or faster growth if the tree was to be left for lumber-log maturity.

This example assumed that 3 prop trees or 2 tie trees could be grown in the space that the saw-timber tree would demand. Many different assumptions can and will be made, but the authors feel that for most situations any tree that is incapable of growing at medium or better vigor and, in addition, of producing a grade 1 or 2 butt log will mature for ties or props.

Similarly, where the choice falls between maturity for ties or props (because the trees have no prospect of achieving lumber-log quality), a reasonable generalization is to consider medium- or high-vigor red oaks and high-vigor white oaks mature for cross ties. The other vigor classes will mature for mine props.

The percentage rates of value increase and index values per tree are not directly comparable for trees of different species groups. Each species group has its own index base. The index values would be comparable only if No. 1 Common and Selects red oak sold for the same price as that of white oak, and of No. 1 Common yellow-poplar. Although differences in the base value do exist, they are not great and tend to maintain a fairly constant relationship to one another. White oak, red oak, and yellow-poplar base grades tend to average within 10 percent of each other. The highest price is usually paid for yellow-poplar, and the next highest for white oak; red oak sells for the lowest prices. Consequently, no great harm will result if direct comparisons are made, provided that where the decision is close a yellow-poplar is favored over either of the oak groups, and a white oak is preferred to a red.

Other considerations relating to the stand may affect the maturity decision. A tree may be otherwise financially mature and still not ready for harvest if it is needed as a seed source. Again, the need for holding the cut within a cutting budget, or of building the growing stock towards optimum diameter-class distributions, may well result in leaving for another cutting cycle some mature trees. In some areas there may be insufficient timber volume to support a commercial cutting operation despite a sprinkling of mature trees.

On the other hand, the owner may be forced to cut some trees in order to obtain a regular income or a regular supply of logs for a sawmill; in this case the desired rate of return has risen, at least temporarily.

Finally, there are two classes of management alternatives that have not been considered in this paper. The first of these is the possibility of managing for pine or for other hardwoods--chiefly hickories, blackgum, and sweetgum. These hardwoods are probably not important alternatives to the species discussed in this paper, but pine is. In most upland forests, pine forms such a valuable component that the forest manager will wish to determine the grades and vigor classes of hardwood trees that should be cut to favor the pine. Some rule of thumb will serve this purpose. For example, the manager might decide that any pine showing promise of reaching sawlog size is a better alternative than any hardwood incapable of growing at medium or high vigor and of producing at least a grade 2 lumber log.

The other important management alternative is the possibility of replacing an existing tree with one or more superior pines or hardwoods grown from seed. This is a problem that merits the attention of the forest manager who is looking ahead more than the next cutting cycle or two. The calculations are made in the same manner as the comparisons between alternative existing trees. That is, against the potential returns of the existing tree must be balanced the returns from the expected tree or trees that could replace it.

## Simplified Marking Guides

For practical application in the woods, the forest manager will wish to prepare a set of readily usable marking instructions from the preceding tables. To facilitate this task, the pertinent data for lumber log trees are condensed in table 8. The table lists, for each vigor class and two rates of return, the largest sizes of trees that should be left to grow for one more five-year period. The diameter spread allows for differences in log height and grade.

In applying the simplified guides, the influence of other trees should be recognized. When trees of low or medium vigor are to be released by cutting, they should be promoted one vigor class before financial maturity is judged. Trees which show imminent promise of improvement in vigor class, grade, or stem length should be permitted to grow at least one more cutting cycle. Where one of two competing trees is to be cut, it is best to take the one of lesser size, grade, or vigor, or the one with poorer prospects for improvement.

Trees that mature for cross ties and mine props will be distinguishable from prospective lumber-log trees because they are interfering with better trees, are unlikely to meet lumber-log standards now or in the future, or are otherwise of good quality but so damaged by fire, insects, or disease that they are poor risks. A working rule for such trees is to utilize those between 14 and 16 inches d.b.h. for cross ties, and to regard those between 8 and 12 inches as financially mature for mine props.

Table 8.--Simplified marking guides for lumber log trees

| Vigor class | Alternative rate of return | |
|---|---|---|
| | 3 percent | 4 percent |
| | D.b.h., inches | |
| | RED OAKS | |
| High | 30-33 | 26-29 |
| Medium | 26-29 | 22-25 |
| Low | 21-24 | 18-20 |
| | WHITE OAKS | |
| High | 27-29 | 23-25 |
| Medium | 23-25 | 20-21 |
| Low | 21-22 | 18-19 |
| | YELLOW-POPLAR | |
| High | 30-31 | 26-27 |
| Medium | 26-27 | 22-24 |
| Low | 21-22 | 19-21 |

In trees below cross-tie size, where the choice is between maturity for ties or props, red oaks of medium and high vigor, and white oaks of high vigor, will mature for cross ties. The other vigor classes will mature for mine props.11/

If these considerations are too complex to be used in the woods, the number of alternatives facing the timber marker may be still further reduced. For example, the spreads of diameters in table 8 could be replaced by single diameters for each species and vigor class. Further, by assuming that better quality and higher vigor trees can be grown from seed, all low-vigor trees and all grade-3 trees showing no promise of improvement can be considered mature for mine props, cross ties, or lumber logs, depending on tree size.

11/. Some white oaks that mature for props or cross ties on the basis of this analysis may be worth keeping for tight cooperage.